Report on Overfitting and Underfitting with Regularization on CIFAR-10

Introduction

This report explores the impact of regularization on the performance of a neural network trained on the CIFAR-10 dataset. The CIFAR-10 dataset consists of 60,000 32x32 colour images across 10 classes, making it a challenging task for image classification. In this study, we investigate the effects of L1 and L2 regularization with varying strengths on the model's accuracy and loss.

Results Summary

The following table summarizes the accuracy and loss achieved by the neural network with different regularization techniques and strengths:

Regularization	Accuracy	Loss
L1 (0.001)	0.4968	1.565565
L1 (0.01)	0.1000	2.451752
L1 (0.1)	0.1000	2.302607
L2 (0.001)	0.6687	1.101754
L2 (0.01)	0.5519	1.547452
L2 (0.1)	0.1000	2.302607

Observations:

1. **L1 Regularization**:
    - **L1_0.001**:
        - Accuracy: 49.68%
        - Loss: 1.5656
        - **Interpretation**: This configuration provides moderate performance, suggesting a balance between underfitting and overfitting, though the accuracy is relatively low.
    - **L1_0.01 & L1_0.1**:
        - Accuracy: 10.00% (for both)
        - **Loss:** 2.4518 (L1_0.01) & 2.3026 (L1_0.1)

        - **Interpretation**: The significant drop in accuracy and the increase in loss indicate severe underfitting, likely due to overly strong regularization penalizing model complexity excessively.

2. **L2 Regularization**:
    - **L2_0.001**:
        - Accuracy: 66.87%
        - Loss: 1.1018
        - **Interpretation**: This configuration achieves the best accuracy, indicating effective regularization that mitigates overfitting while maintaining model complexity.
    - **L2_0.01**:
        - Accuracy: 55.19%
        - Loss: 1.5475
        - **Interpretation**: Performance declines with stronger regularization, showing a shift towards underfitting.
    - **L2_0.1**:
        - Accuracy: 10.00%
        - Loss: 2.3026
        - **Interpretation**: Like L1 at higher strengths, L2_0.1 causes severe underfitting, as indicated by minimal accuracy and high loss.

Analysis:

- **L1 Regularization**: The L1 regularization strength of 0.001 is the most effective within this set, though it still results in relatively low accuracy. Higher L1 strengths (0.01 and 0.1) lead to severe underfitting, as the model becomes too simplistic to capture the patterns in the data.
- **L2 Regularization**: L2 regularization with a strength of 0.001 yields the best performance, balancing model complexity with the prevention of overfitting. Increasing the strength to 0.01 and 0.1 progressively harms model performance, suggesting underfitting.

Justification for Chosen Regularization Strength

Based on the observations, the L2 regularization with a strength of 0.001 seems to be the most suitable choice for the CIFAR-10 dataset. This configuration achieves a reasonably high

accuracy of 66.87 while maintaining a low loss of 1.1018. The model exhibits some signs of overfitting, but it is still performing well compared to the other configurations.L2 regularization is generally preferred over L1 regularization because it tends to produce more stable and generalizable models. L1 regularization can lead to sparse weight vectors, which may not always be desirable in complex tasks like image classification. It’s important to note that the optimal regularization strength can vary depending on the specific dataset, model architecture, and training hyperparameters. Further experimentation with different regularization strengths or techniques, such as dropout or batch normalization, may help improve the model's performance and generalization capabilities.

Conclusion

In this study, we explored the impact of L1 and L2 regularization on the performance of a neural network trained on the CIFAR-10 dataset. The results suggest that L2 regularization with a strength of 0.001 provides a good balance between overfitting and underfitting, achieving the highest accuracy while maintaining a reasonably low loss. However, further optimization and experimentation may be necessary to fully mitigate overfitting and improve the model's generalization ability on this challenging dataset.